

1       What is claimed is:

2       1.    An apparatus for use in a mass spectrometer to enhance  
3 the performance thereof, said apparatus comprising:

4           means for detecting sample ions;

5           means for trapping sample ions; and

6           a differential amplifier;

7       ~~wherein a space encompassed by said detecting means is also~~  
8 encompassed by said trapping means;

9       wherein said sample ions are trapped within said space by  
10 said trapping means by application of electrical potentials onto  
11 said trapping means; and

12       wherein said sample ions are detected by said detecting  
13 means.

14  
15       2.    An apparatus according to claim 1, wherein said means  
16 for detecting sample ions is arranged in a substantially  
17 cylindrical manner.

18  
19       3.    An apparatus according to claim 1, wherein said  
20 detecting means utilizes charge induction to detect ions.

1           4.    An apparatus according to claim 1, wherein said sample  
2    ions are detected in a manner similar to that in an FTICR mass  
3    spectrometer.

4  
5           5.    An apparatus according to claim 1, wherein said  
6    trapping means comprises four RF electrodes.

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8           6.    An apparatus according to claim 1, wherein said  
9    detection means comprises four detection electrodes.

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11          7.    An apparatus according to claim 1, wherein said  
12   apparatus is linear.

13  
14          8.    A multipole device according to claim 1, wherein  
15   elements of said trapping means are held at a DC potential to  
16   trap ions within said detecting means.

1           9.    A multipole device for transferring, trapping and  
2   analyzing ions in a mass spectrometer, said multipole device  
3   comprising:

4               a plurality of electrodes, said electrodes comprising a  
5               plurality of RF electrodes, and at least one  
6               first; and

7               second detection electrodes;

8               at least two trapping electrodes; and

9               a differential amplifier having first and second  
10              inputs;

11             wherein said plurality of electrodes are arranged such that  
12     no two RF electrodes are adjacent and no two detection electrodes  
13     are adjacent;

14             wherein all of said first detection electrodes are  
15     electrically connected and all of said second detection  
16     electrodes are electrically connected;

17             wherein said first detection electrodes are connected to  
18     said first input and said second detection electrodes are  
19     connected to said second input;

20             wherein one of said trapping electrodes is positioned at  
21     each end of said plurality of electrodes such that when an

1 appropriate DC potential is applied thereto said ions become  
2 trapped within said plurality of electrodes; and .

3 wherein said differential amplifier measures the potentials  
4 on said detection electrodes to determine the m/z ratio of said  
5 ions.

6  
7 10. A multipole device according to claim 9, wherein said  
8 plurality of electrodes are arranged in a substantially circular  
9 manner.

10  
11 11. A multipole device according to claim 9, wherein said  
12 plurality of electrodes detect trapped ions by charge induction.

13  
14 12. A multipole device according to claim 9, wherein said  
15 plurality of electrodes detect ions in the manner of FTICR mass  
16 spectrometry.

17  
18 13. A multipole device according to claim 9, wherein said  
19 apparatus contains four RF electrodes, and four detection  
20 electrodes.

1           14. A multipole device according to claim 9, wherein said  
2 device is linear.

3  
4           15. A multipole device according to claim 9, wherein said  
5 RF electrodes of said device have the same potential and  
6 frequency as said trapping electrodes.

7  
8           16. A multipole device according to claim 9, wherein said  
9 device is further comprised of a single set of said RF  
10 electrodes, and said detection electrodes divide the multipole  
11 device into an analyzing section positioned between two trapping  
12 sections.

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14           17. A multipole device according to claim 16, wherein said  
15 detection electrodes in said trapping sections are held at a DC  
16 potential to trap ions in said analyzing section.

1           18. A linear multipole device for transferring, trapping  
2 and analyzing ions in a mass spectrometer, said multipole device  
3 comprising:

4           four RF electrodes;

5           four electrodes comprising two first and two second  
6           detection electrodes;

7           two trapping electrodes; and

8           a differential amplifier having first and second  
9           inputs;

10          wherein said electrodes are arranged such that no two RF  
11 electrodes are adjacent and no two detection electrodes are  
12 adjacent;

13          wherein both of said first detection electrodes are  
14 electrically connected and both of said second detection  
15 electrodes are electrically connected;

16          wherein said first detection electrodes are connected to  
17 said first input and said second detection electrodes are  
18 connected to said second input;

19          wherein one of said trapping electrodes is positioned at  
20 each end of said electrodes such that when an appropriate DC  
21 potential is applied thereto said ions become trapped within said

1 plurality of electrodes; and

2 wherein said differential amplifier measures the potentials  
3 on said detection electrodes to determine the  $m/z$  ratio of said  
4 ions.

5  
6 19. A linear multipole device according to claim 18,  
7 wherein all of said electrodes are circularly arranged.

8  
9 20. A linear multipole device according to claim 18,  
10 wherein said detection electrodes detect trapped ions by charge  
11 induction.

12  
13 21. A linear multipole device according to claim 18,  
14 wherein said detection electrodes detect said ions in the manner  
15 of FTICR mass spectrometry.

16  
17 22. A linear multipole device according to claim 18,  
18 wherein said RF electrodes have the same potential and frequency  
19 as said trapping electrodes.

1           23. A linear multipole device according to claim 18,  
2 wherein said detection electrodes divide said device into three  
3 sections comprising one analyzing section located between two  
4 trapping sections.

5  
6           24. A method for analyzing ions in a mass spectrometer,  
7 ~~said method comprising the steps of:~~

8           directing ions into a multipole device having an  
9                       analysis region positioned between, and coaxially  
10                      with, first and second trapping regions;  
11           trapping said ions within said analysis region by  
12                      creating electric fields across said trapping  
13                      regions; and  
14           analyzing said ions;

15           wherein said analyzing region includes exciting said ions  
16 within said analysis region and detecting said ions from within  
17 said analysis region.

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19           25. A method according to claim 24, wherein said ions are  
20 detected within said analysis region by a plurality of detection  
21 electrodes.



1           26. A method according to claim 25, wherein said plurality  
2 of detection electrodes comprises four detection electrodes,  
3 allowing detection of said excited, ions in two cycles.  
4

5           27. A method according to claim 24, wherein said trapping  
6 regions are held at a higher DC potential than said analysis  
7 region to form a substantially homogeneous quadrupolar field  
8 within said analysis region.

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11           28. A method according to claim 24, wherein said exciting  
12 is achieved by applying an electrical pulse between electrodes of  
13 said analysis region.

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15           29. A method according to claim 28, wherein said exciting  
16 causes said ions to move in a substantially circular orbit around  
17 a central axis of said analysis region.

18           30. A method according to claim 28, wherein said exciting  
19 causes said ions to move in a substantially oval orbit around a  
20 central axis of said analysis region.  
21

1           31. A method according to claim 24, wherein said ions are  
2 detected using charge induction.

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4           32. A method according to claim 24, wherein said ions are  
5 detected in the manner of FTICR mass spectrometry.

1 33. A mass analyzer comprising:

2 at least four RF electrodes;

3 at least four detect electrodes; and

4 at least two DC electrodes;

5 wherein said RF electrodes and detect electrodes are  
6 arranged in a cylindrically symmetric manner about a central  
7 axis;

8 wherein said RF electrodes and detect electrodes have inner  
9 surfaces which are arc shaped;

10 wherein every RF electrode is arranged between and parallel  
11 with two detect electrodes;

12 wherein every detect electrode is arranged between and  
13 parallel with two RF electrodes;

14 wherein sample ions are substantially trapped on the axis of  
15 said mass analyzer by the action of an RF electric field  
16 generated via said RF electrodes;

17 wherein said sample ions are substantially prevented from  
18 exiting the ends of said mass analyzer by the action of a DC  
19 electric field generated via said DC electrodes; and

20 wherein said detect electrodes are used to detect the ions  
21 in said mass analyzer.

1           34. An apparatus according to claim 33, wherein said  
2 detecting means utilizes charge induction to detect ions.  
3

4           35. An apparatus according to claim 33, wherein at least  
5 some of said RF electrodes, DC electrodes, or detect electrodes  
6 extend through a pumping restriction.  
7

8           36. An apparatus according to claim 33, wherein at least  
9 some of said RF electrodes, DC electrodes, or detect electrodes  
10 are used to assist in the transport of ions from an ion source  
11 into said mass analyzer.  
12

13           37. An apparatus according to claim 35, wherein said  
14 electrodes which extend through said pumping restriction are used  
15 in part to assist in the transport of ions from an ion source  
16 into said mass analyzer.  
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